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Acoustic Testing of the Cassini Spacecraft and Titan IV Payload Fairing

Part 2—Results

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SUMMARY

A Cassini spacecraft simulator in a full scale 60 ft high Titan IV payload fairing with various acoustic blanket designs and configurations was recently tested in a large reverberant acoustic chamber. A first part companion paper provides the test configuration details and other background information. This paper addresses the results obtained from this test program. Emphasis will be on the effects of the new blanket designs on reducing the payload fairing's internal acoustics and the vibration response of the spacecraft's Radioisotope Thermoelectric Generators. Other results discussed include: the effect of blankets on fairing vibration, the effect of partial blanket coverage on acoustics and vibration and the effect of tuned vibration absorbers.

INTRODUCTION

In October 1997, NASA will launch the Cassini spacecraft (ref. 1), to explore Saturn and its moons, with a Titan IV/Centaur launch vehicle. The electric power source for the Cassini mission are three mission critical Radioisotope Thermoelectric Generators (RTGs). To avoid an extremely costly (\$25 to 30 M) requalification of the RTGs, a major acoustic blanket development and test effort was initiated and funded by NASA Lewis Research Center (NASA Lewis), the launch vehicle integrator for the Cassini mission. Specifically, the goal was to test verify a new acoustic blanket which would reduce the expected acoustic environment for the Cassini RTGs by 3 dB at 200 and 250 Hz, when compared with the baseline Titan IV blanket system environment.

A wealth of engineering vibroacoustic information was obtained from this testing. The major test results are documented in this paper. The background information of this test program is provided elsewhere (refs. 1 and 2). Besides NASA Lewis and JPL, other organizations involved in this joint effort included Lockheed Martin Astronautics (LMA, formerly Martin Marietta Technologies Incorporated, MMTI), McDonnell Douglas Aerospace (MDA), Aerospace Corporation, Analex Corporation and Cambridge Collaborative Incorporated.

EFFECT OF TYPE OF ACOUSTIC BLANKET ON PLF INTERIOR ACOUSTICS AND RTG VIBRATION

The full scale payload fairing (PLF) tests were very successful in meeting the primary objectives (ref. 1) of reducing the PLF's interior acoustics and the RTG vibration response with new blanket designs. Referring to the test matrix of figure 1, the key tests were Tests 2, 4 and 7. Test 2 established the baseline measurements using the Titan IV baseline blanket (3 in. thick, with no internal barrier), whereas Test 4 (V10, 5 in. thick with 0.88 psf internal barrier) and Test 7 (V5, 6 in. thick with 0.44 psf internal barrier) would allow the calculation of the delta effect of the new blanket designs above the baseline design. (Tests 4 and 5 are essentially repeats from a blanket impact point of view. The effects of the tuned vibration absorbers (TVAs) on the spacecraft vibration response will be discussed later.)

The acoustic excitation on the external side of the PLF simulated the Titan IV flight external specification and was based on the average of six control microphones. The test to test repeatability of this external excitation was extremely good (range of 0.4 dB over first 7 tests at 200 and 250 Hz). However to account for even these small variations all test data was adjusted to represent the level which would be obtained if the acoustic excitation was exactly the Titan IV external specification.

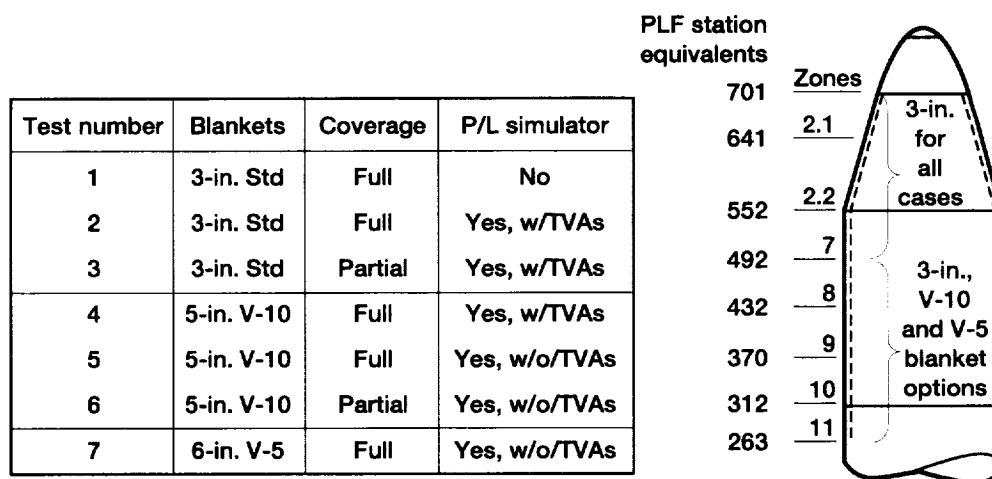


Figure 1.—Test matrix for PLF testing [2].

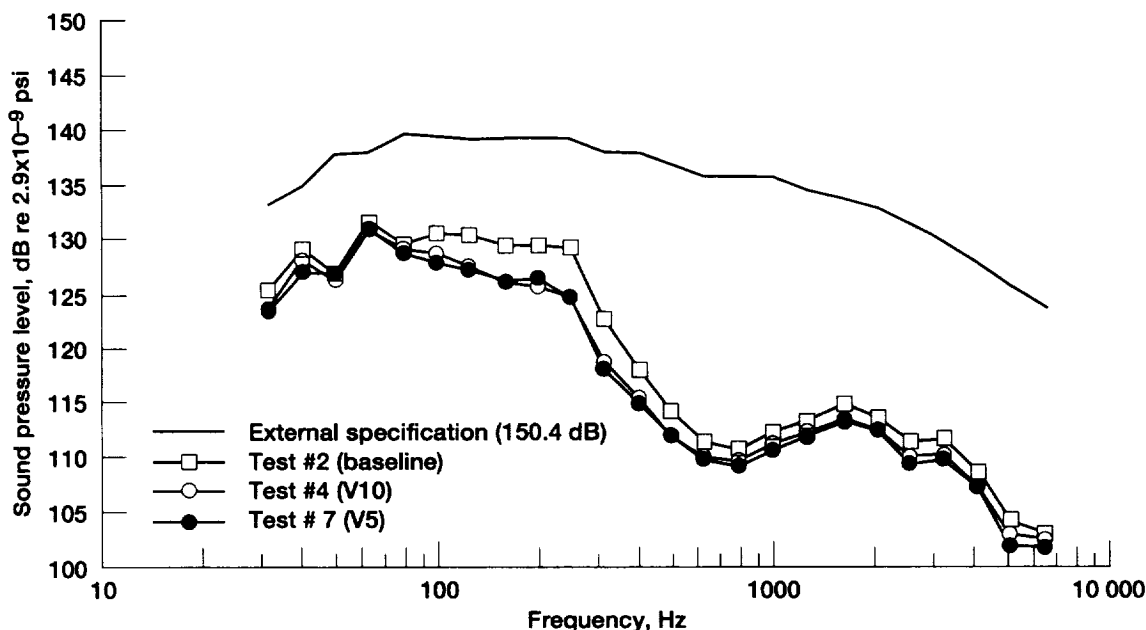


Figure 2.—Effect of blanket type on PLF interior acoustics [3].

Figure 2 illustrates the main results of the testing. The external specification is the desired PLF external specification. Test 2 data shows the average of 10 microphones in PLF zones 9 and 10 (the region of high interest for the RTGs (ref. 1)) when the Titan IV baseline blankets are utilized. Similarly the Tests 4 and 7 data represent the same microphone average when the V10 and V5 blankets are substituted for the baseline blankets in PLF zones 8 to 11. From figure 2 one can see that the new blankets were very successful in reducing the PLF interior acoustics to levels below those provided by the baseline blankets. Also whereas this improvement is largest at 200 to 400 Hz, it is a positive improvement at all frequencies.

Figure 3 illustrates the delta improvement for the V10 and V5 blankets. This figure shows that both the V10 and the V5 blankets were successful in reducing the RTG acoustic environment by 3 dB at 200 and 250 Hz. For the V10 blanket this improvement is 3.5 dB at 200 Hz and 4.0 dB at 250 Hz. For the V5 blanket the improvement is 3.2 dB at 200 Hz and 4.6 dB at 250 Hz. Further information on the effect of the acoustic blanket type on acoustics is found in the references 2 to 5.

Of course, the ultimate goal was to reduce the RTG vibration response to prevent a vibration requalification test of the RTG. An indication of the vibration reduction achieved is shown in figure 4. This figure shows the

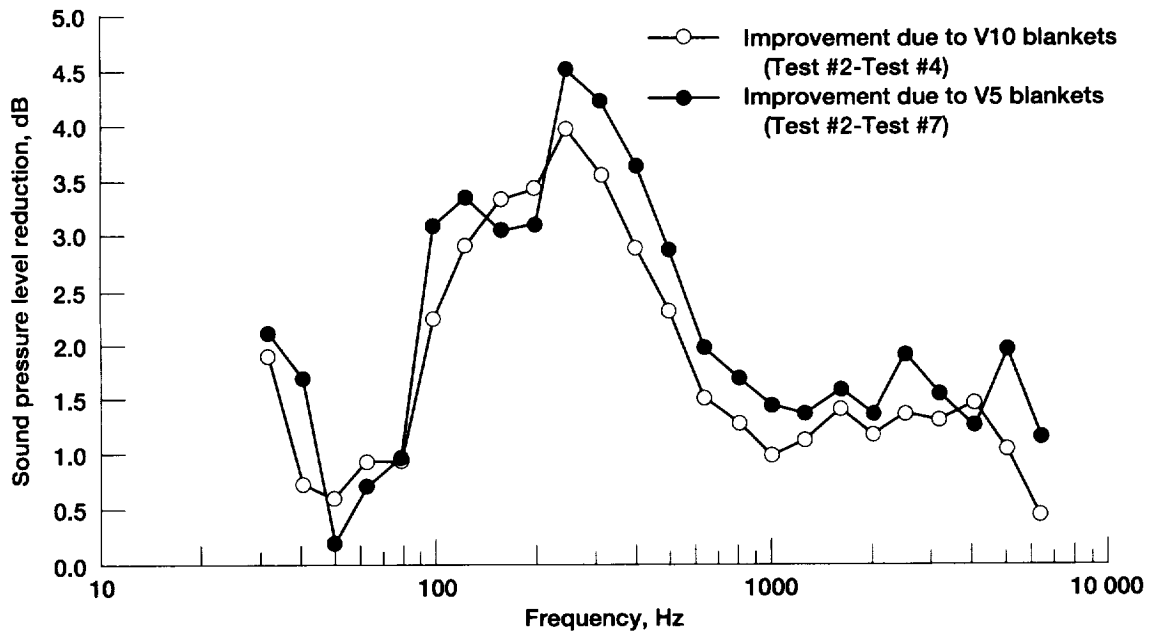


Figure 3.—Delta acoustic improvement using new blanket designs [3].

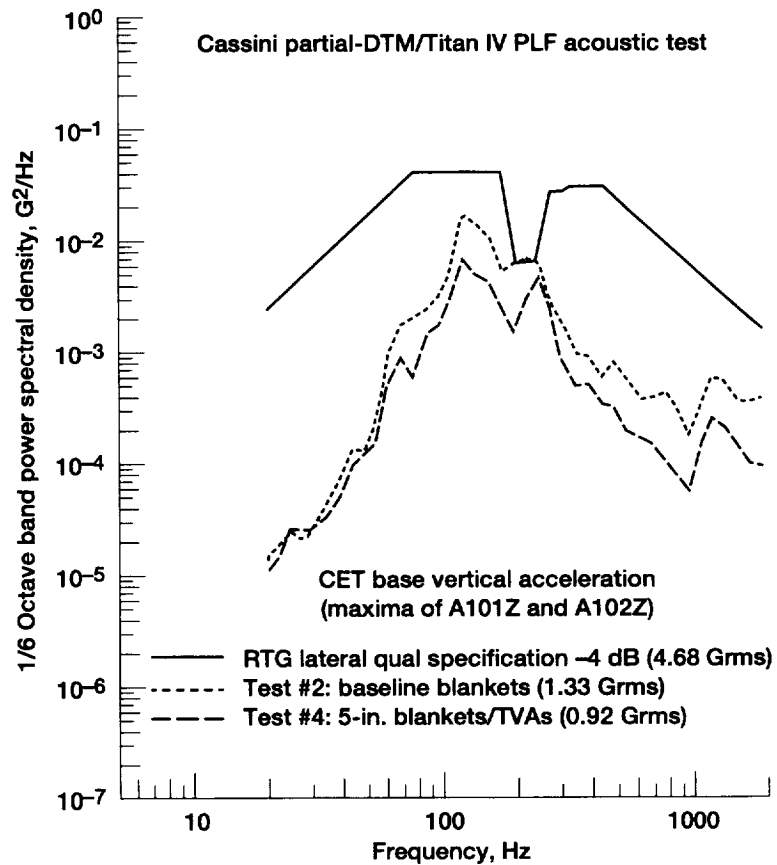


Figure 4.—Effect of new blanket design on RTG vibration [10].

acceleration PSD (power spectral density) response at the base of the RTG dynamic simulator for the baseline blanket and for the V5 (6 in.) blanket. One can see substantial improvement, particularly in the 200 and 250 Hz frequencies. The RTG vibration response is documented in detail by JPL (refs. 6 and 7).

The technical assessment of the test data is that both of the new barrier blankets (V5 and V10) exceeded the goal of reducing the acoustic environment by more than 3 dB and significantly reduced the RTG vibration response, at the 200 and 250 Hz critical frequencies. No detrimental effects were seen at any frequency or in other PLF zones.

Since both of the new barrier blankets had similar acoustic performances, other programmatic considerations (primarily the blanket weight) lead to the selection of the V5 blankets (6 in. thick with internal barrier) as the final blanket design for the Cassini mission. The V5 blanket is approximately four times the weight of the Titan IV baseline blanket.

Because of the success of this blanket developmental test program, vibration requalification of the RTGs for the Cassini mission is not necessary. The utilization of the new V5 blankets to reduce the acoustic excitation and the subsequent vibration of the RTGs eliminates the need to manufacture additional RTG units for a requalification test program, thus saving NASA ~\$20 to 25 M in manufacturing cost and \$5 M in testing cost.

EFFECT OF BLANKET COVERAGE ON PLF INTERIOR ACOUSTICS

To improve the acoustic modeling of payload acoustics as a function of blanket coverage area, the results of Tests 3 and 6 (partial blanket coverage) were compared with the results of Tests 2 and 5 (full coverage) respectively. Figure 5 illustrates the results. Here partial blanket coverage is defined (ref. 1) as equal to 75 percent of the full blanket coverage.

Reducing the coverage for the baseline barrier results in higher acoustic levels, with increases greater than 1 dB at 300 Hz and above. The same coverage reduction for the V10 blanket, with the internal barrier, results in even greater increases in the acoustic levels, with delta increases of 1 dB at 170 Hz and above. The effect of reduced blanket coverage is therefore greater for the barrier blanket than for the baseline blanket. This is attributed to the reduction of coverage area affecting the transmission loss more than the absorption characteristics of the blanket. The effectiveness of the barrier blanket is primarily due to its increased transmission loss characteristics. More information is available in references 2, 4 and 5.

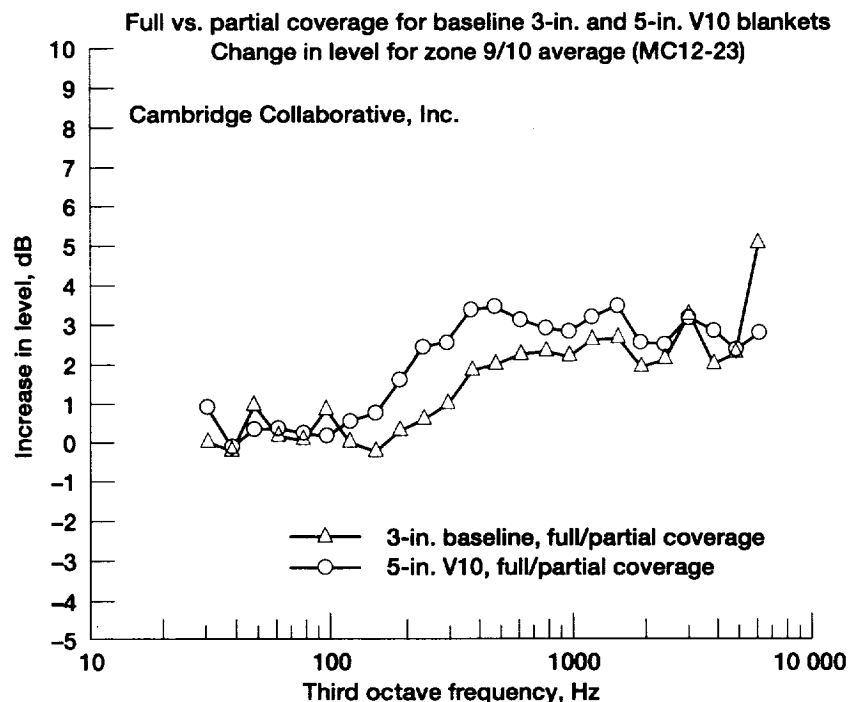


Figure 5.—Effect of blanket coverage on PLF interior acoustics.

EFFECT OF BLANKET COVERAGE AND TYPE ON PLF VIBRATION

The effect of the blankets on the PLF vibration was of great interest to MDA, the fairing manufacturer. Test 8 was added by LMA and MDA to obtain test data for a completely unblanketed PLF with no spacecraft simulator. MDA instrumented the PLF (ref. 1) with accelerometers throughout all 8 tests.

Adding acoustic blankets resulted in a lower PLF vibration response when compared to the unblanketed PLF response. Figure 6 illustrates this effect for the unblanketed Test 8 and for the baseline blanket Tests 2 and 3. The average acceleration spectral densities (ASD) for three accelerometers (A11, A15, A16 (ref. 1)) are compared. The effect of going from no blankets to full blanket coverage is 8 to 10 dB over most of the frequency range. The reduced blanket coverage test (50 percent local reduction in fairing bay, 25 percent reduction overall) still results in about 7 dB reduction in the ASD from the no blanket case. The benefit seen by adding acoustic blankets to the unblanketed fairing is therefore not linear.

The effect of blanket type on PLF vibration is illustrated in figure 7. Here a normalized response, adjusted for PLF skin thickness and test acoustic level differences, shows that the blanket type does not affect the reduction benefit above 200 Hz. Below 200 Hz, the heavier the blanket the more reduction was observed. This observation, attributed to blanket weight, could also be due to differences in blanket designs and damping characteristics.

Other conclusions were also drawn from the test data. It was found that the acoustic blanket effect extended beyond the local blanket boundary, that is the PLF vibration response directly under the blanket is similar to the response of an adjacent unblanketed PLF skin. Also the blankets were found to have a global effect, reducing the vibration of completely unblanketed fairing regions. Additional information on blanket effects on PLF vibration is found in reference 8.

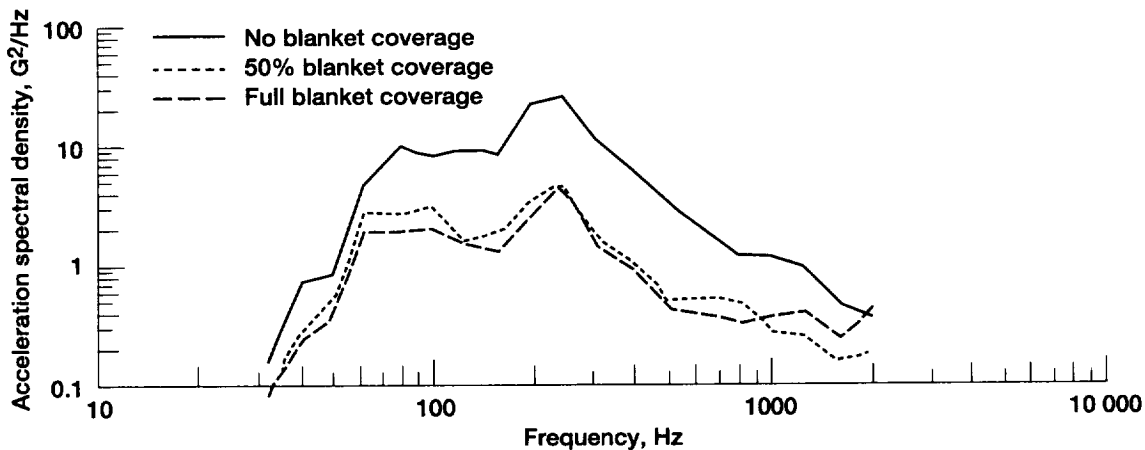


Figure 6.—Effect of blanket coverage on PLF vibration [8].

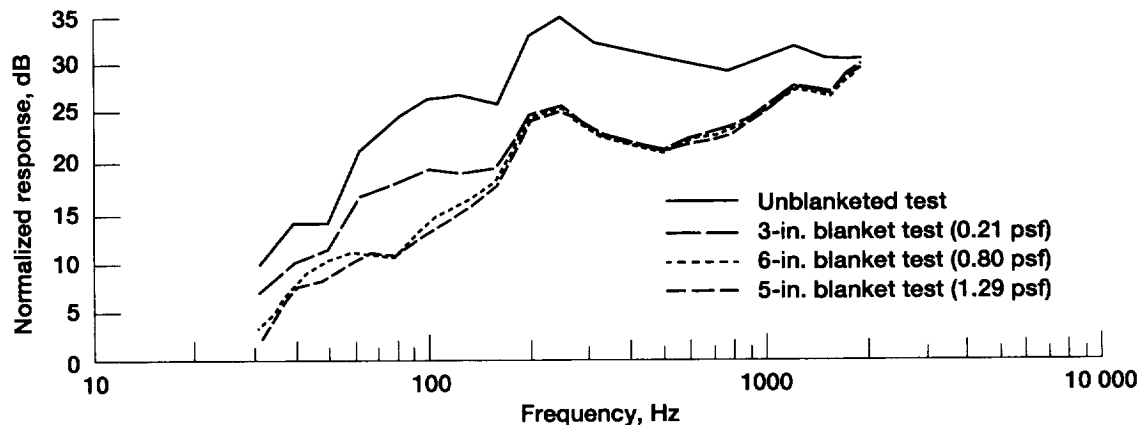


Figure 7.—Effect of blanket type on PLF vibration [8].

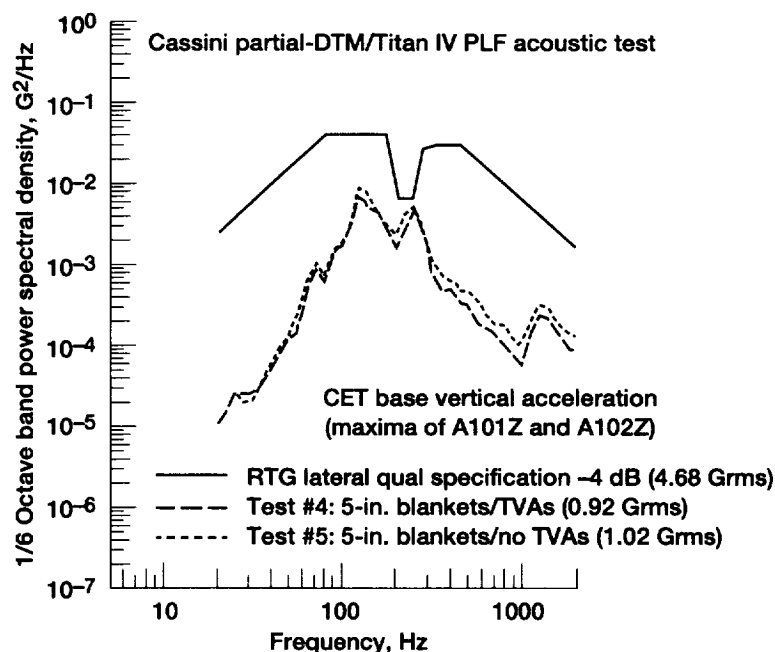


Figure 8.—Effect of TVAs on RTG vibration [10].

EFFECT OF TVAS ON RTG VIBRATION

The TVA design was developed by JPL as an alternative method to reduce the RTG vibration level (refs. 1, 6 and 7). The TVAs were tested at JPL in the Cassini partial DTM configuration and the TVAs looked promising for reducing the RTG vibration response. However, when tested as part of the PLF test the results obtained were not as good as expected. Figure 8 illustrates the TVA performance seen when comparing the RTG base response from Tests 4 and 5.

It was later determined that the TVAs may have mistuned over time during the PLF test series. This TVA reliability concern, coupled with the success of the new blankets, led to JPL's decision to hold the usage of TVAs in reserve for the Cassini mission. Although the blankets selected for the Cassini mission weight significantly more than the TVAs, the effective weight impact of the TVAs and the blankets are nearly the same on the Cassini mission performance.

COMPARISON OF TEST TO FLIGHT DATA

By comparing ground test data to identically located Titan IV flight data it was noted that the correlation was poor, especially in the low frequencies. An example is shown in figure 9. Such differences between ground and flight measurements is likely due to differences between a test chamber's reverberant field and the directional traveling wave field seen on a launch pad.

By using the available flight and ground test data, LMA derived (ref. 5) a preliminary efficiency factor, or correction factor, to convert from flight levels to chamber measurements or vice versa. A plot of this efficiency factor is shown in figure 10. This factor is negative in frequencies greater than 125 Hz, denoting that the flight data is higher than the ground test data for these frequencies.

Again this efficiency factor should be considered preliminary due to using limited flight measurements in its derivation and the possibility that such factors may be unique to particular chambers or chamber/fairing combinations.

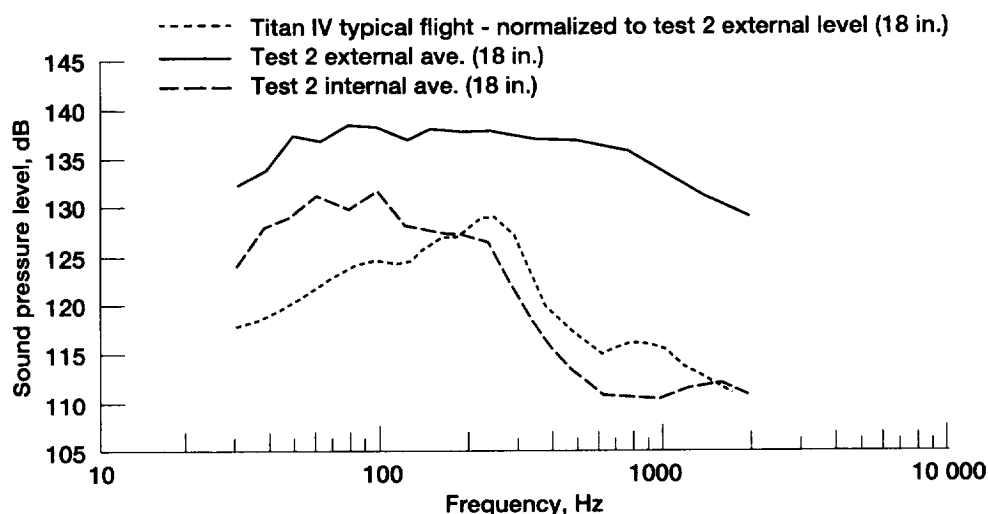


Figure 9.—Spectrum shape comparison - flight versus test [5].

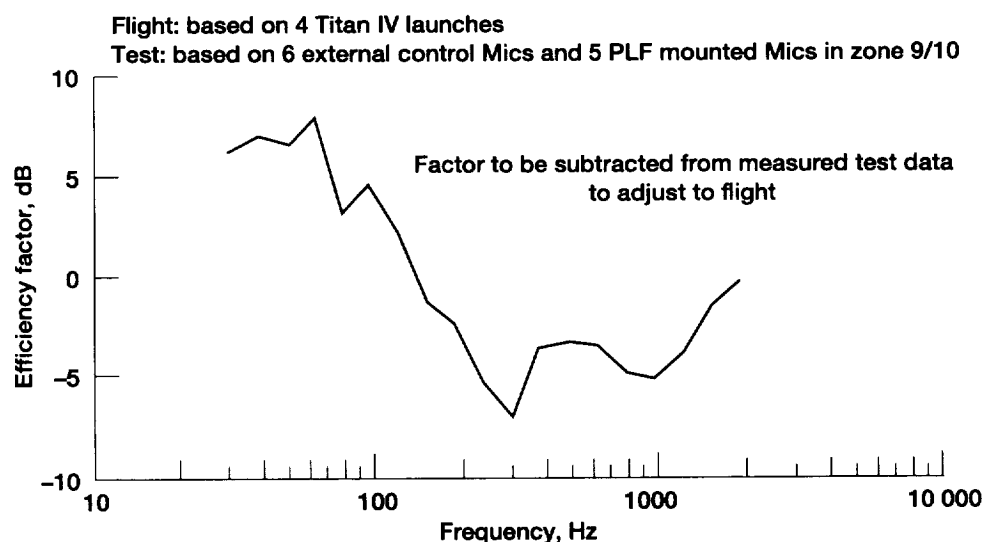


Figure 10.—Preliminary efficiency factor [5].

OTHER RESULTS

Due to limited space, numerous other test findings are not reported here, but are summarized elsewhere (refs. 2 to 9). Among these items are: (1) fill factor effects of Cassini Huygens Probe, (2) effect of HGA on separating the PLF interior acoustics, (3) comparisons of ground test measurements to past and future mission flight measurements, (4) effect of distance from PLF wall on measurements, (5) Cassini spacecraft simulator response measurements, (6) Titan IV PLF noise reduction and absorption characteristics, (7) differences between spacecraft mounted and PLF wall mounted measurements and (8) the distribution of PLF interior acoustics and PLF vibration.

CONCLUSIONS

A multi-organizational test effort, led by NASA Lewis, has been successfully completed. A Cassini spacecraft simulator in a full scale 60 ft high Titan IV payload fairing with various acoustic blanket designs and configurations was recently tested in a large reverberant acoustic chamber. The test goals of reducing the PLF interior acoustics and RTG vibration response were met and reported here. As a result the V5 newly designed blankets will be used for the Cassini mission and thereby prevent a \$25 to 30 M requalification program of the Cassini's RTGs. Additionally, a subset of the wealth of acoustic and vibration test data obtained during this test program is discussed in this paper.

ACKNOWLEDGMENTS

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